ILC Si Pixel Detector R&D at LBNL

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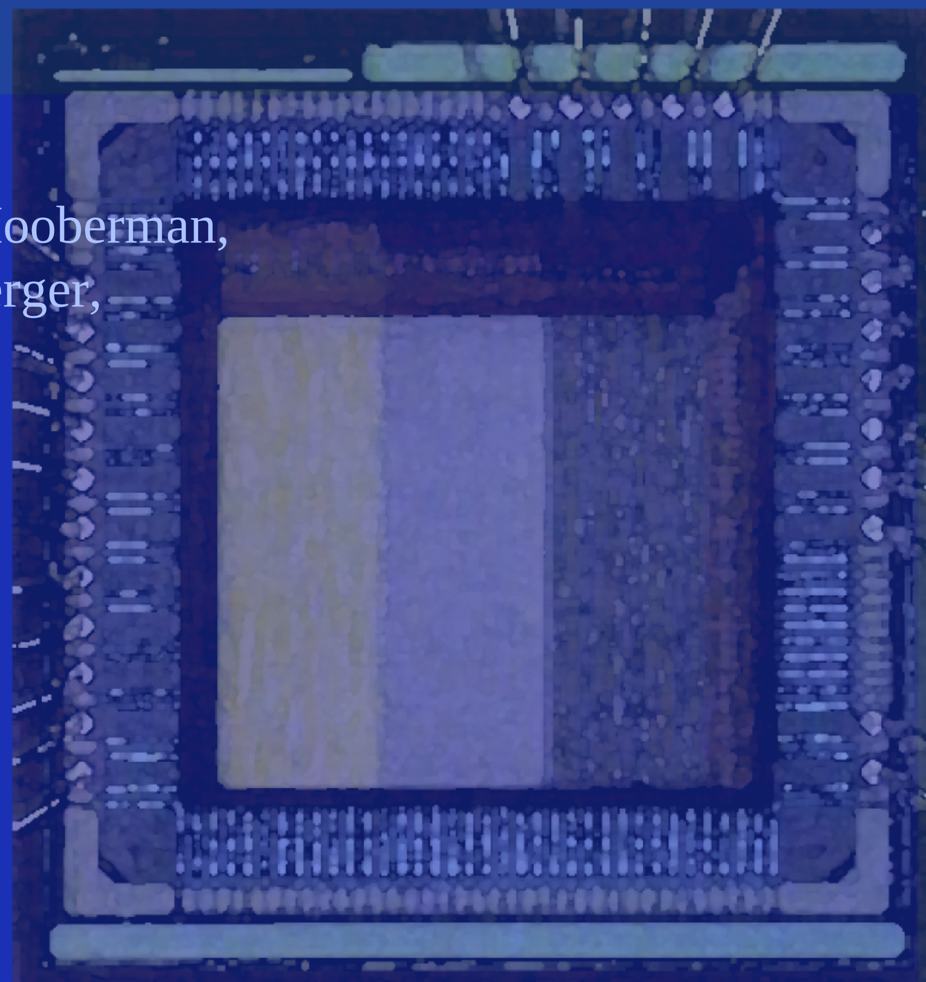


ECFA ILC Workshop, November 14, 2005

ILC Pixel R&D at LBNL supported by 3-year Lab Directed R&D funding started in October 04;

Activity builds on synergies with existing research on pixel sensors at LBNL for application from HEP (ATLAS) to Nuclear Science (STAR), electron microscopy and syncrotron light source experiments (Engineering Division);

R&D targets sensor and readout development, sensor backthinning, pixel module engineered design and data analysis;

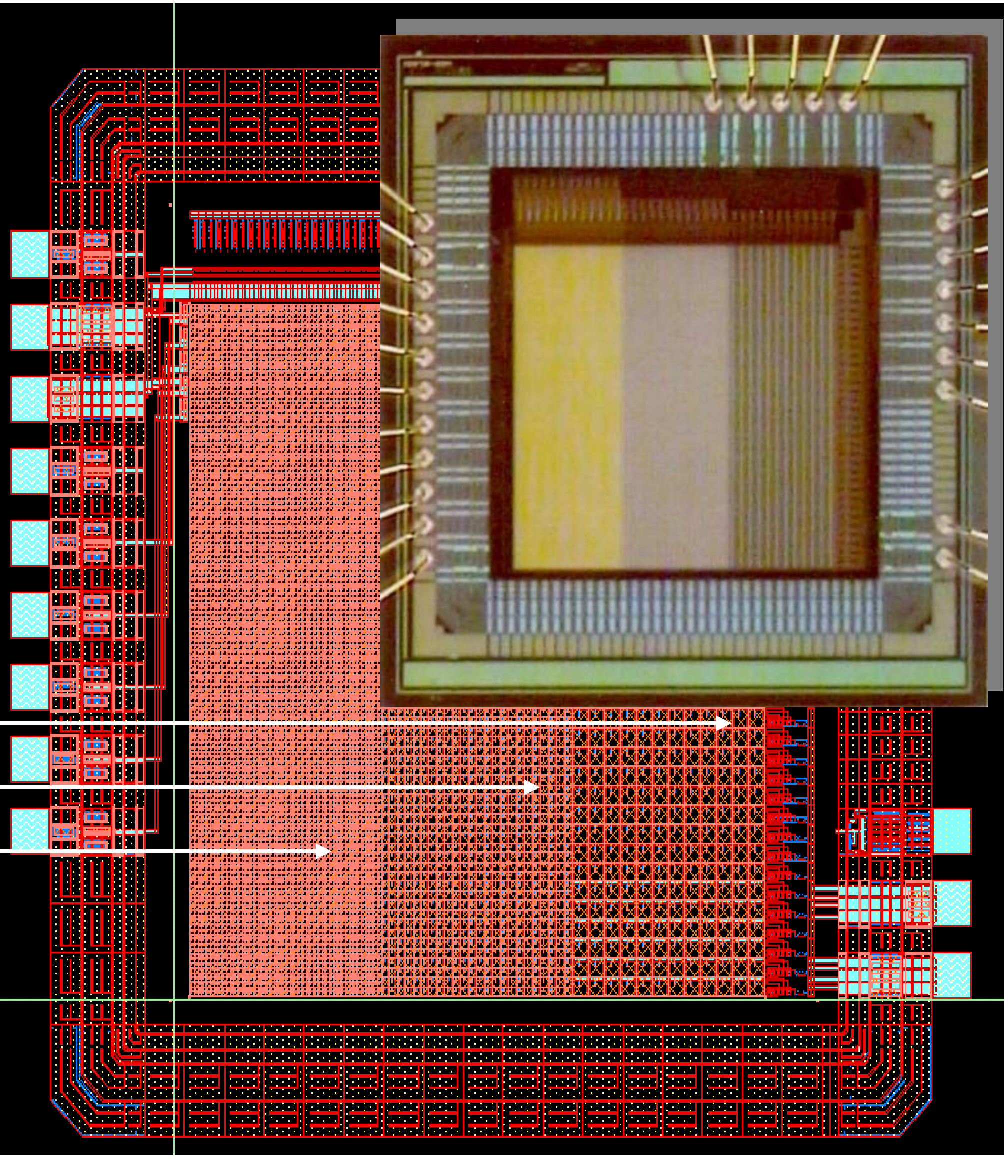
LDRD embedded in broader ILC project at LBNL and includes UC faculty, LBNL staff, postdocs, graduate students and technical support.

0.35 OPTO AMS Test Structure

Development of LDRD Test Structure
design in collaboration with LBNL Engineering Division: Submitted April 05
AMS 0.35µm CMOS-OPTO process through MOSIS:
14µm epi layer, low dark current

Three Pixel Geometries
12 x 36   40 µm pixels
24 x 72   20 µm pixels
48 x144 10 µm pixels
Analog output

Test structures back from foundry in August, tests ongoing.



200 keV Electron Microscope Test

Test at the JEOL 200CX TEM electron microscope at LBNL NCEM

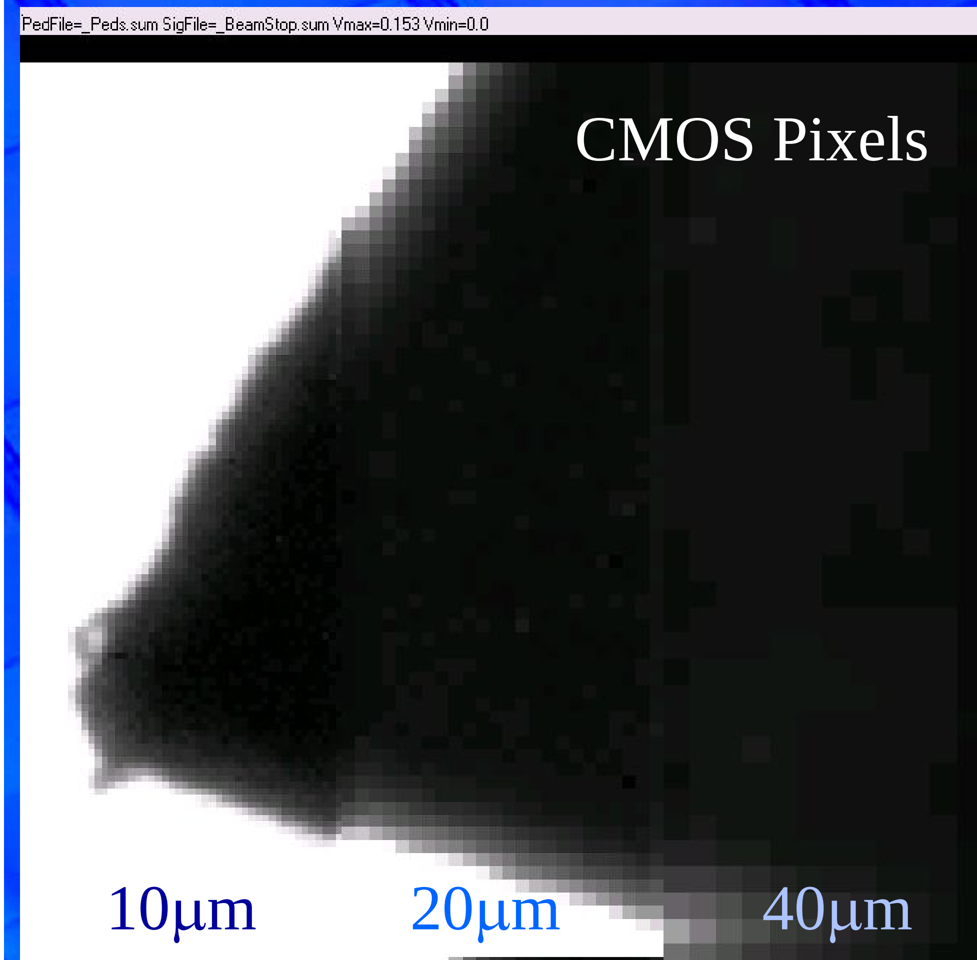
Mount detector on the modified GATAN bright field STEM;

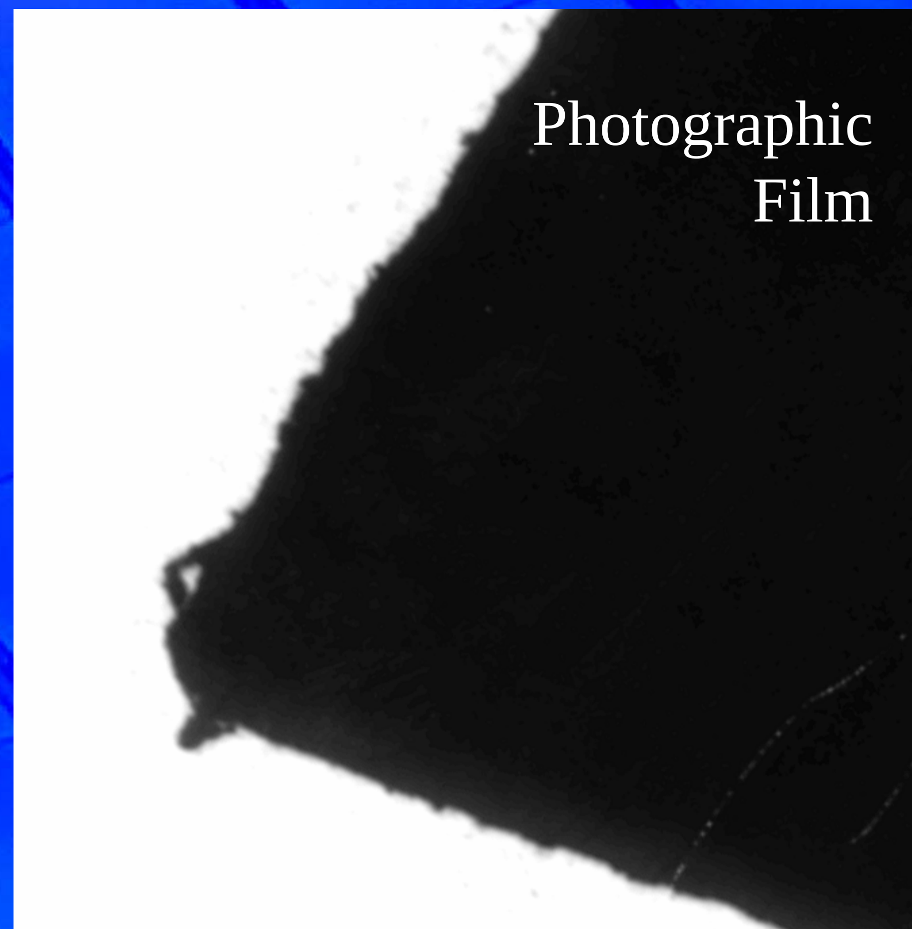
Cycle Reset, 100 ms Integration, Digitisation; acquire 200 images with ~10 primary e^- (200 keV)/image;

Simulation:
200 keV electron beam deposits 5.3 keV in 14 µm epi layer.

200 keV Electron Microscope Test

Beam Stop Image with 200 keV e^-



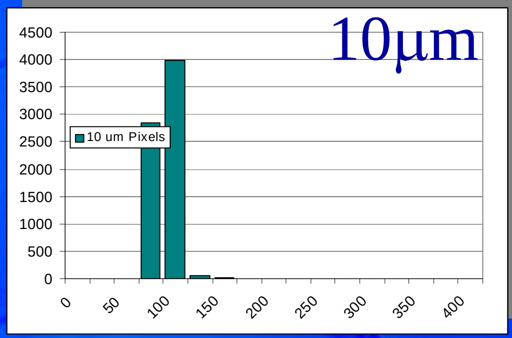


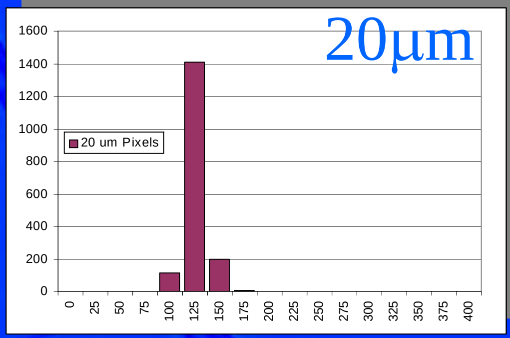
200 keV Electron Microscope Test

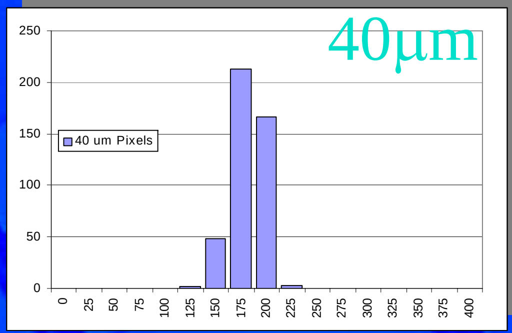
Determine noise and gain at room temperature from flat field at low intensity:

	10µm	20µm	40µm
Noise (mV)	3.0	4.4	6.5
Gain (mV/e$^-$)	25	29	35
Single e$^-$ S/N	8.3	6.6	5.4

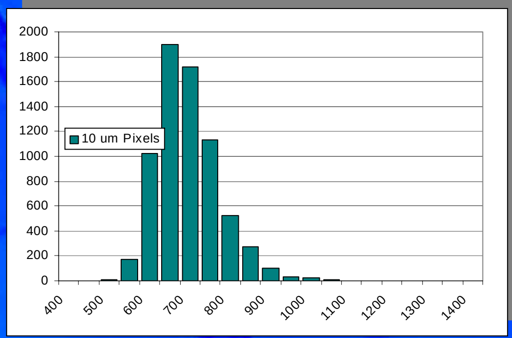
Noise

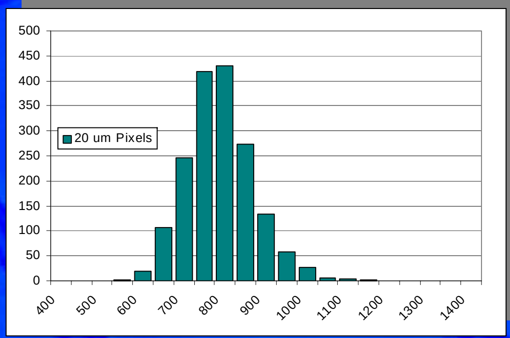


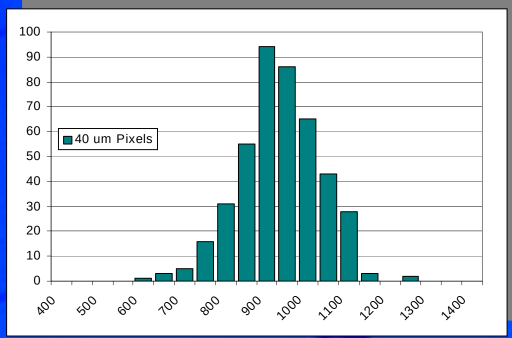




Signal



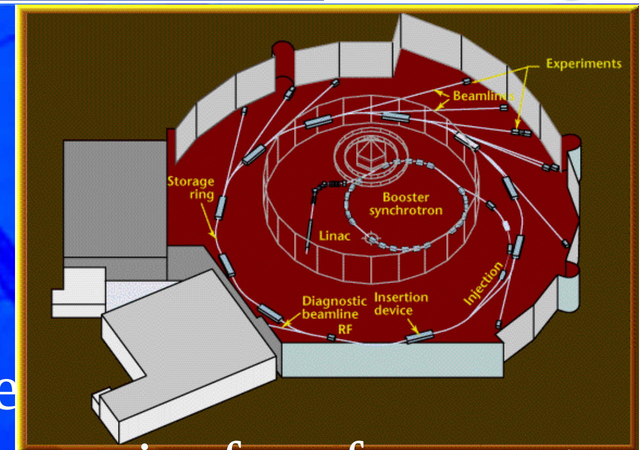




ALS Beam Test

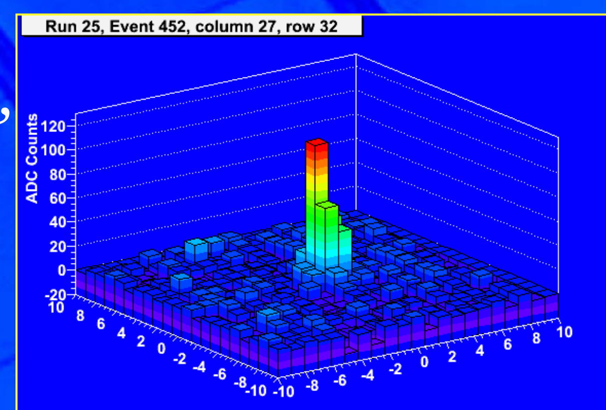
Test at BTS beam line of Advanced Light Source

- Use single bunch of primary 1.5 GeV e^- beam, tune particle flux by electron gun voltage and magnetic focusing;



- Trigger on beam pickup signal, readout sequence consists of Reset, 1 ms Integration and pixel read; acquire four frames at 1 Hz booster cycle frequency, tune beam on third frame; keep detector in reset between two bunches, 14-bit digitisation performed on readout board, interface with DAQ PC, LabView online program;

- Initialise pixel noise and pedestals with beam off, update during run on empty frames; LabView ASCII data converted into LCIO format; Cluster analysis performed offline using C++ program and ROOT; test different clustering algorithms.



ALS Beam Test

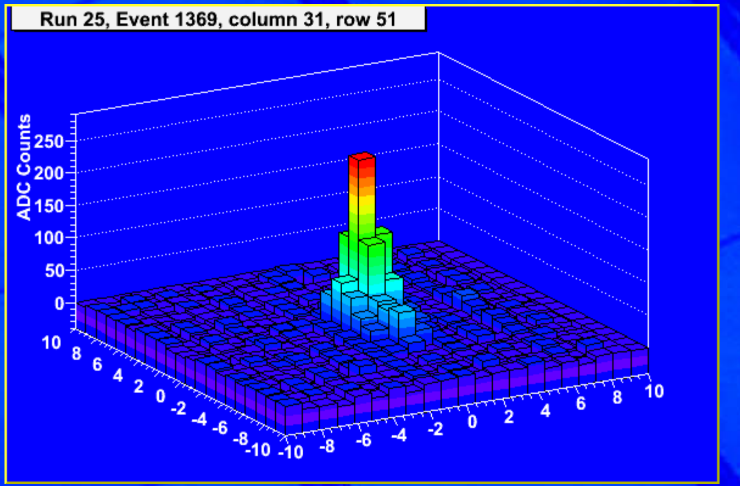
Low Intensity Run

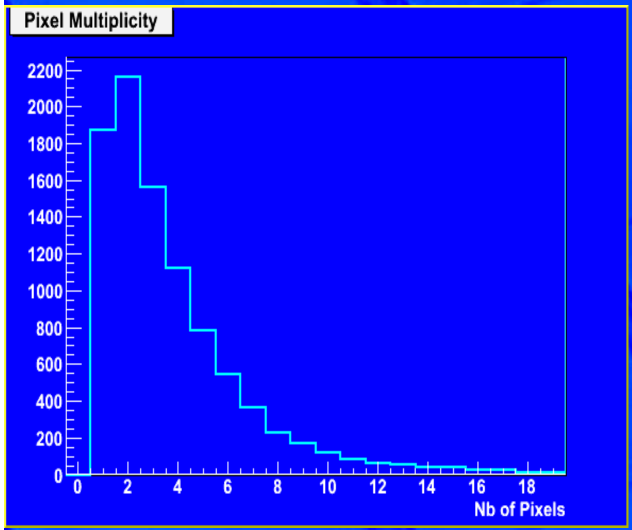
focused low intensity primary beam
~ 15 clusters/event

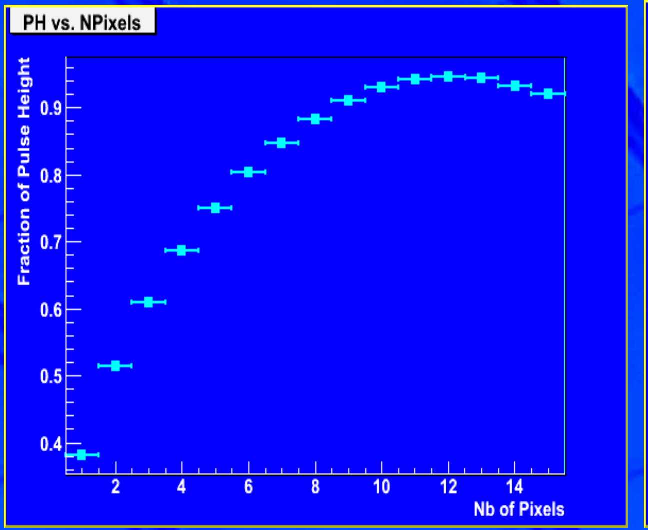
10x10μm² pixels

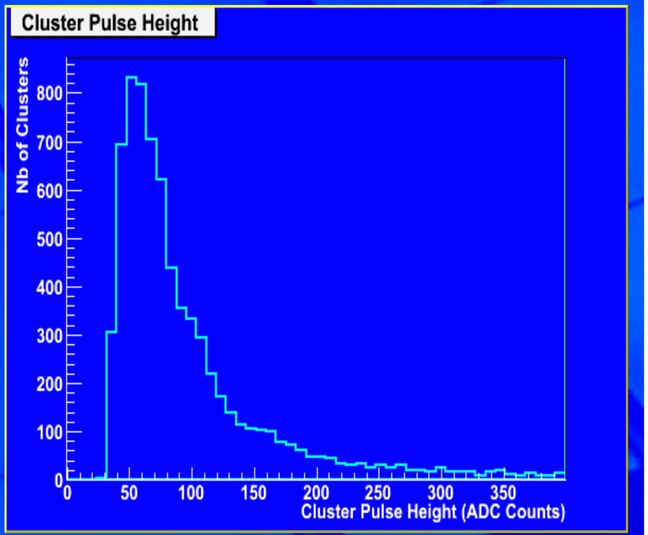
<Nb. of Pixels>	<S/N>
3.72	9.8

Preliminary









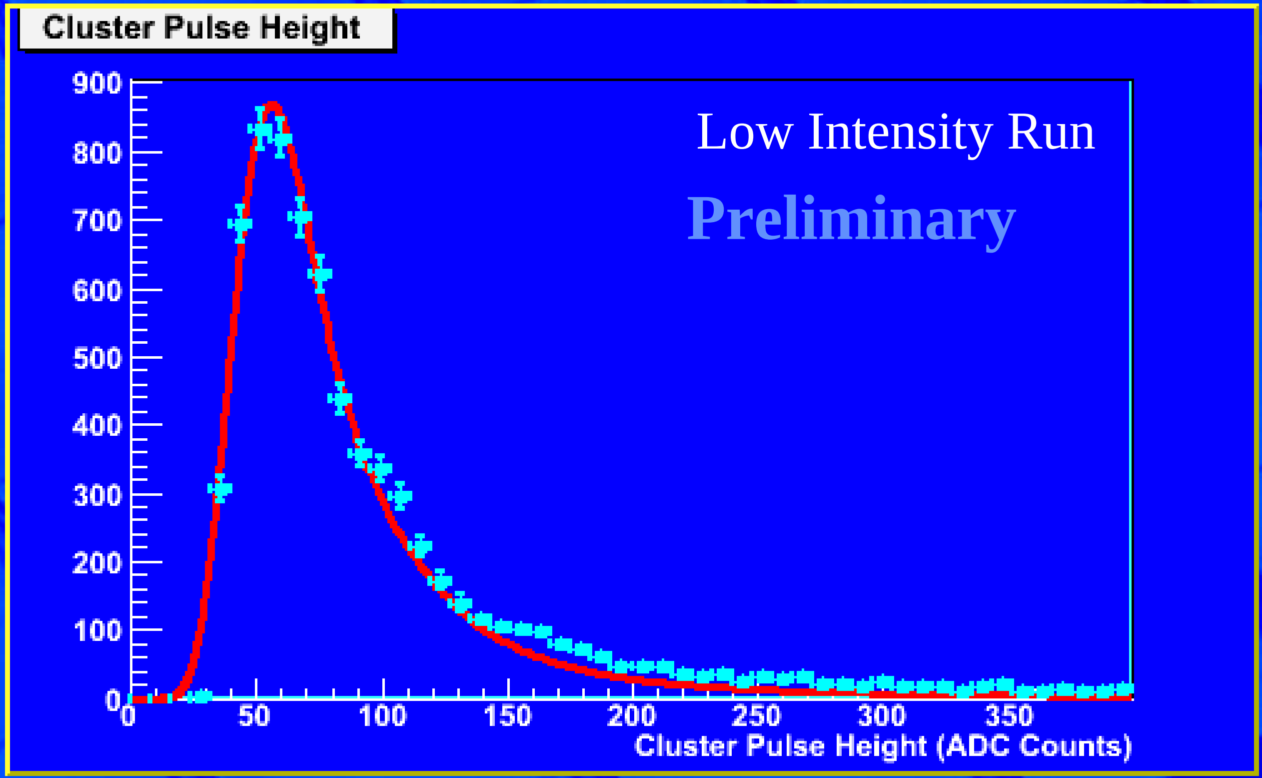
ALS Beam Test

Need to understand relatively large noise (x1.3 in trigger mode): contribution from readout board, chip held in reset, temperature;

Compare measured signal with energy deposition prediction based on thin straggling function formalism (by H. Bichsel) :

14 μm of Si: expect most probable energy loss of 2.74 keV = 746 e^-.

Started GEANT4 simulation of 1.5 GeV e^- on thin Si to study spatial spread of energy deposition.



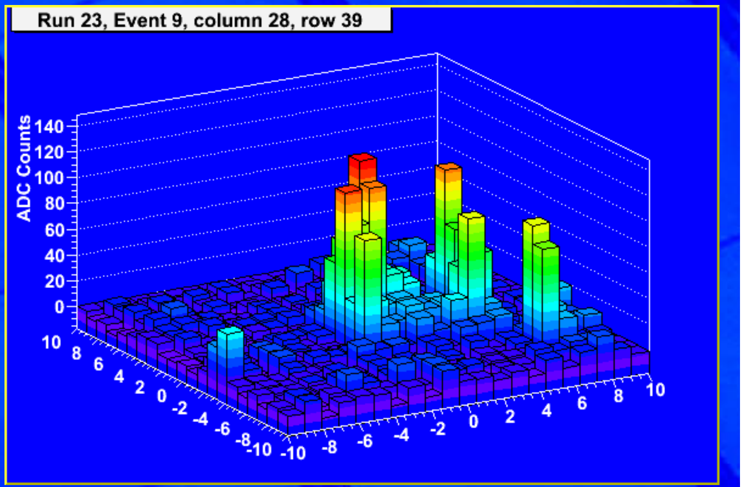
ALS Beam Test

High Intensity Run

defocused primary beam at higher current

~150 clusters/event, substantial secondaries:

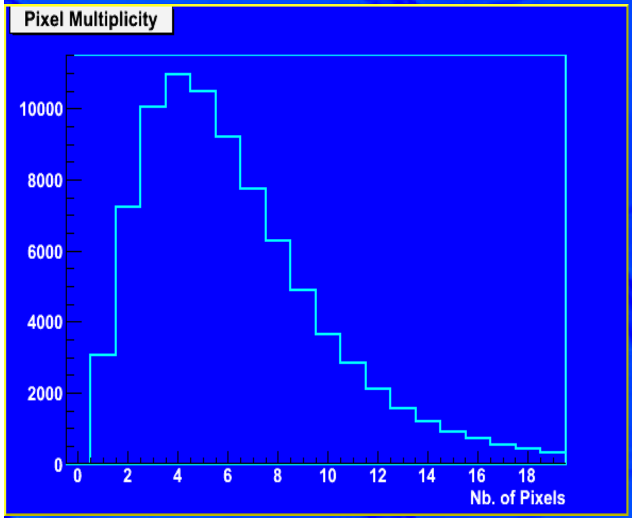
Occupancy ~ 15% in 10x10μm^2 section

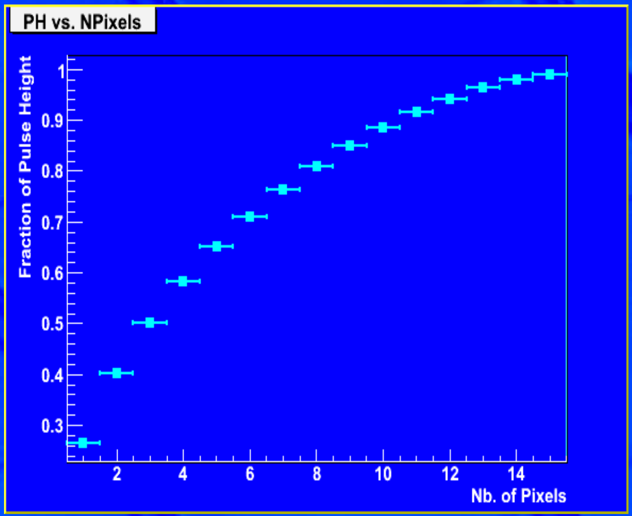


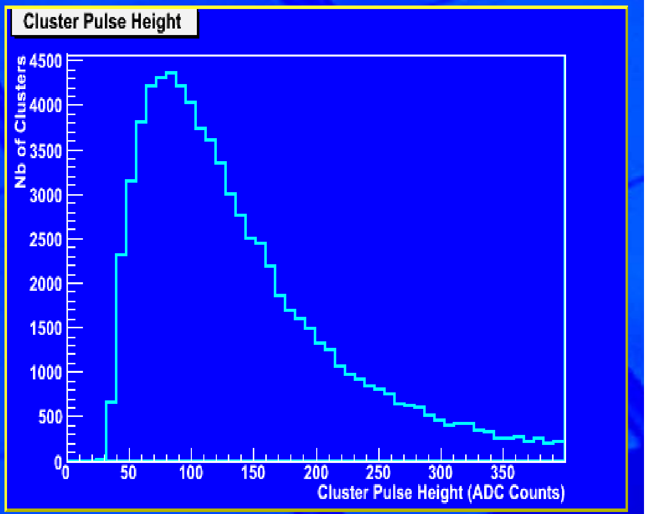
10x10μm^2 pixels

<Nb. of Pixels>	<S/N>
6.23	11.1

Preliminary





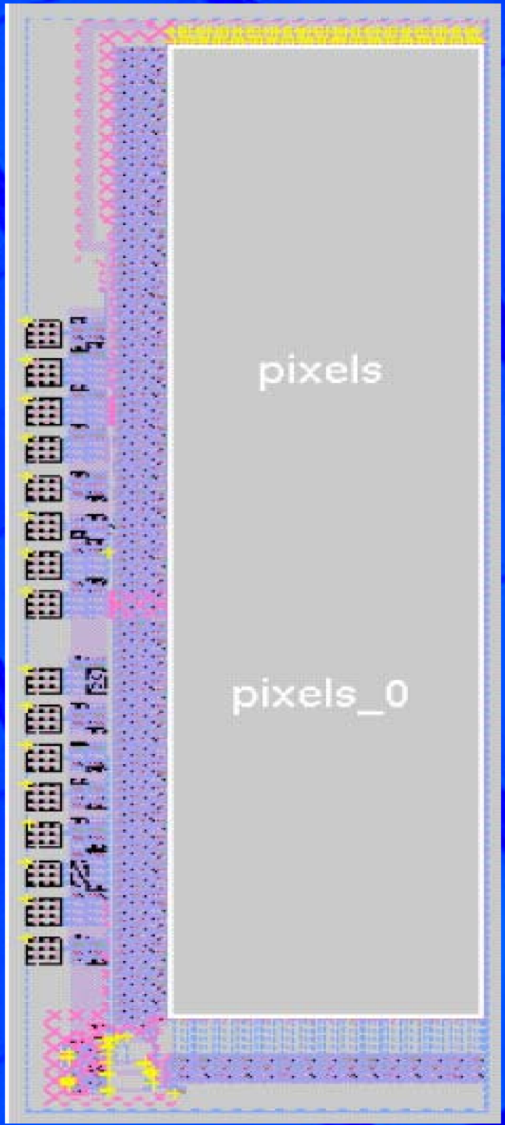


0.50-AMIS Test Structure

Pixel structure designed at UC Irvine (S. Kleinfelder) in collaboration with LBNL STAR group:

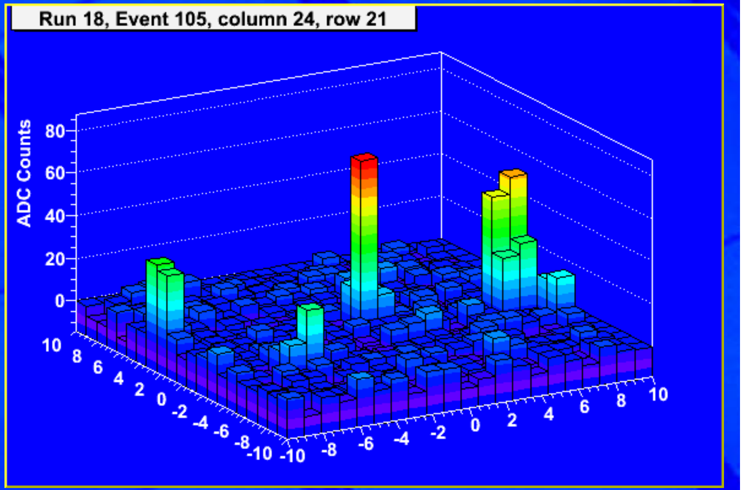
- 3T pixels 20 µm pitch with diode size of 13 µm, 20 µm, 32 µm, 41µm and 54 µm;
- 0.50µm AMIS C5 process

submitted in October 04,
tested in Lab with 55Fe and at ALS.



ALS Beam Test

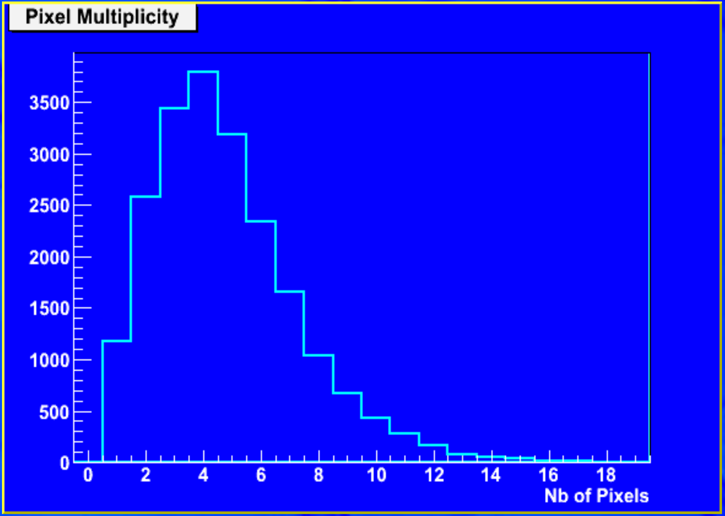
Cycle Reset and two-frame read,
write data to memory only on ALS trigger,
perform CDS;

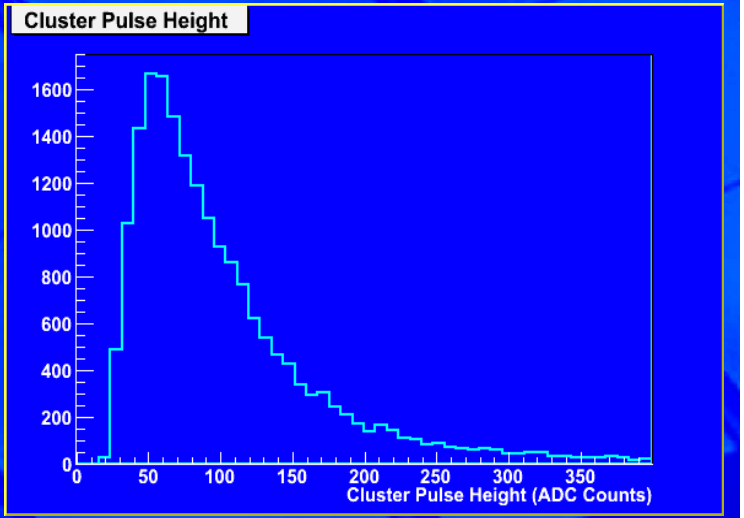


<u>$10 \times 10 \mu m^2$ pixels</u>

<Nb. of Pixels>	<S/N>
4.27	14.9

Preliminary

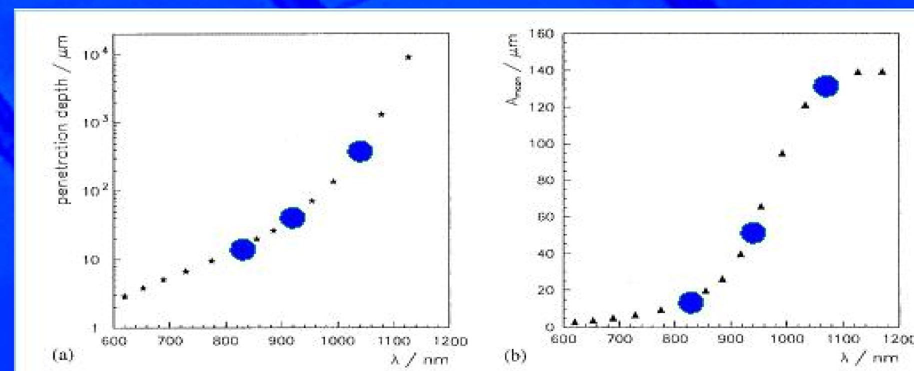




Backthinning Tests

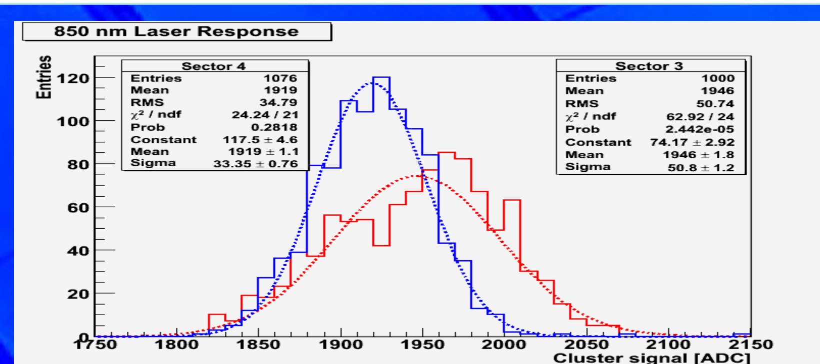
Characterise Mimosa-5 chips using Laser system and 1.5 GeV e^- beam; chip backthinning to 35-50μm at Bay Area partner company: compare results to determine changes in signal generation and charge collection;

Laser system to mimic m.i.p. in Si:



Diode lasers driven by fast pulse generator to produce laser pulses from 0.5 - 100 ns

laser beam collimated to < 10 μm



choice of laser wavelengths to probe charge collection through detector thickness

First two chips characterised and ready to be sent to backthinning, expect first results by early 06.

Future Plans

- Pursue characterisation of first chip in 0.35 OPTO, cool detector to understand noise performance;
- ALS Beam Test in early 06 with small pixel telescope to study chip efficiency, tracking and cluster shape discrimination for low energy e^-;
- Design work for next ILC test chip started: 20 μm pitch with in-pixel CDS and on-chip 4-5 bit pipelined ADC, low power (~ 1 mW/channel) and 25 MHz readout;
- Study backthinned Mimosa-5 sensors to characterise charge collection and process yield;
- Develop engineered model of pixel module in collaboration with LBNL STAR Pixel group (LCRD).